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(54) Mixing apparatus with rotary agitator

(57) A mixing apparatus comprises a cylindrical tank 12 having a down-pumping turbine bladed agitator 14 the shaft 13 of which is displaced radially from the axis of the tank by a distance of from about 1/10 to 1/4 of the tank diameter and at least two baffles 17, preferably equally-spaced, mounted on the inside wall of the tank, each of the baffles comprises a rectangular member extending substantially from the bottom of the tank to the maximum slurry level of the tank and having a radial width of between about 1/36 and 1/100 of the tank diameter. Four equally-spaced baffles are particularly preferred, each having a radial width of about 1/50 of the tank diameter.

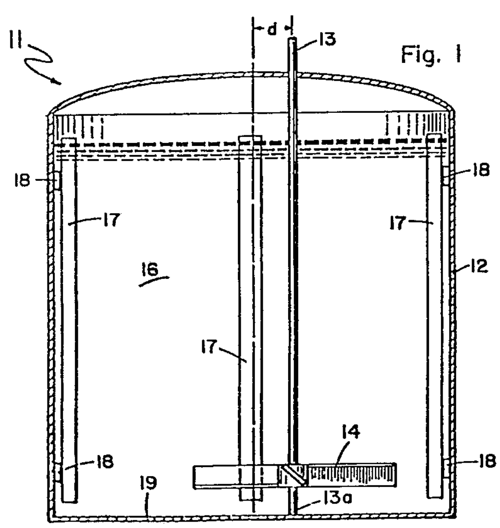

Fig. 1

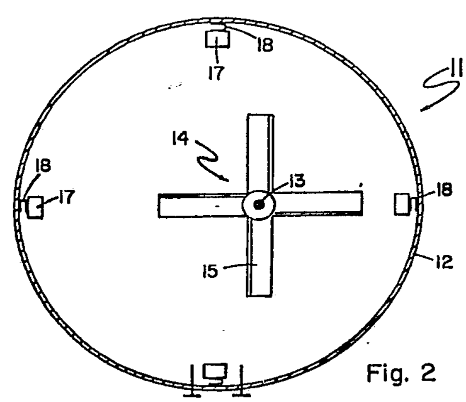

Fig. 2

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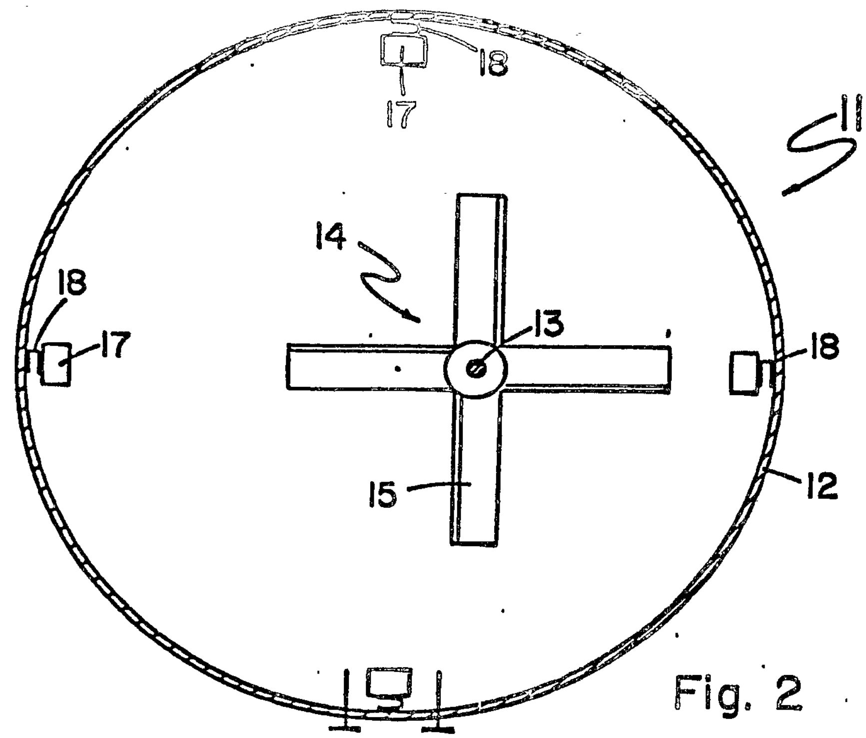

Fig. 2

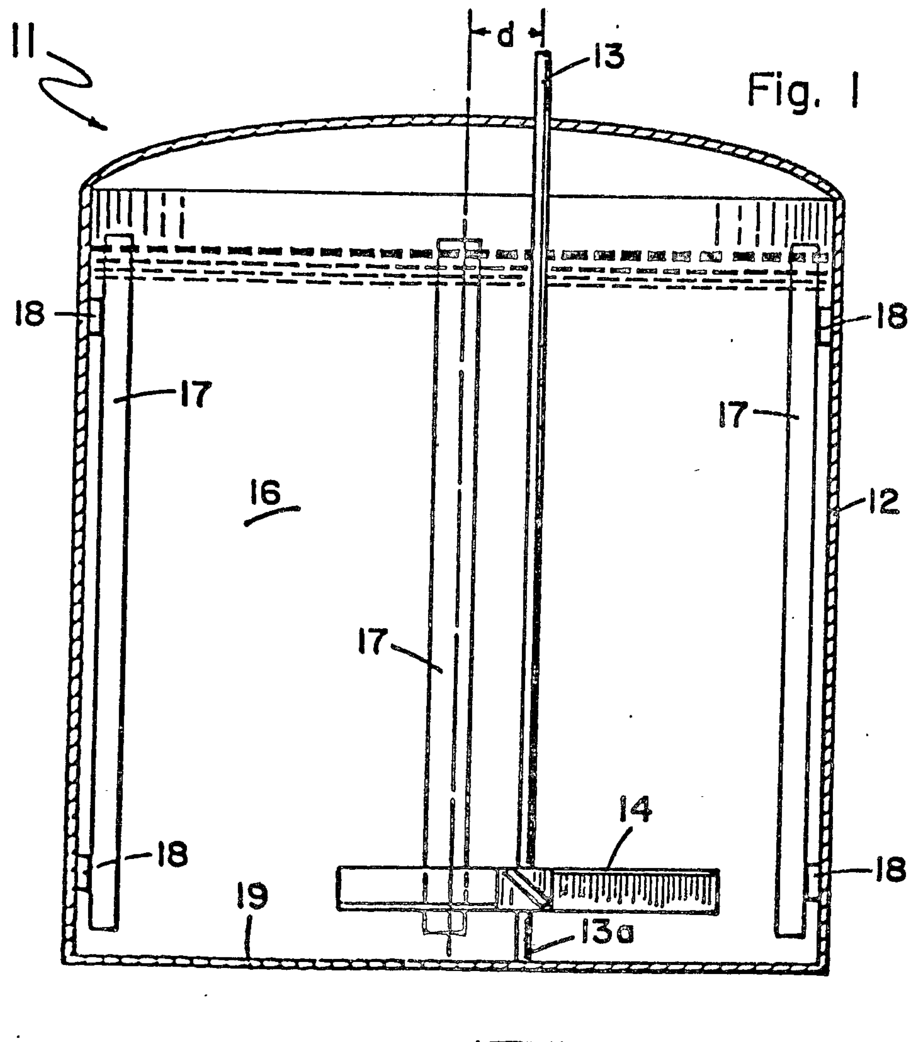

Fig. 1

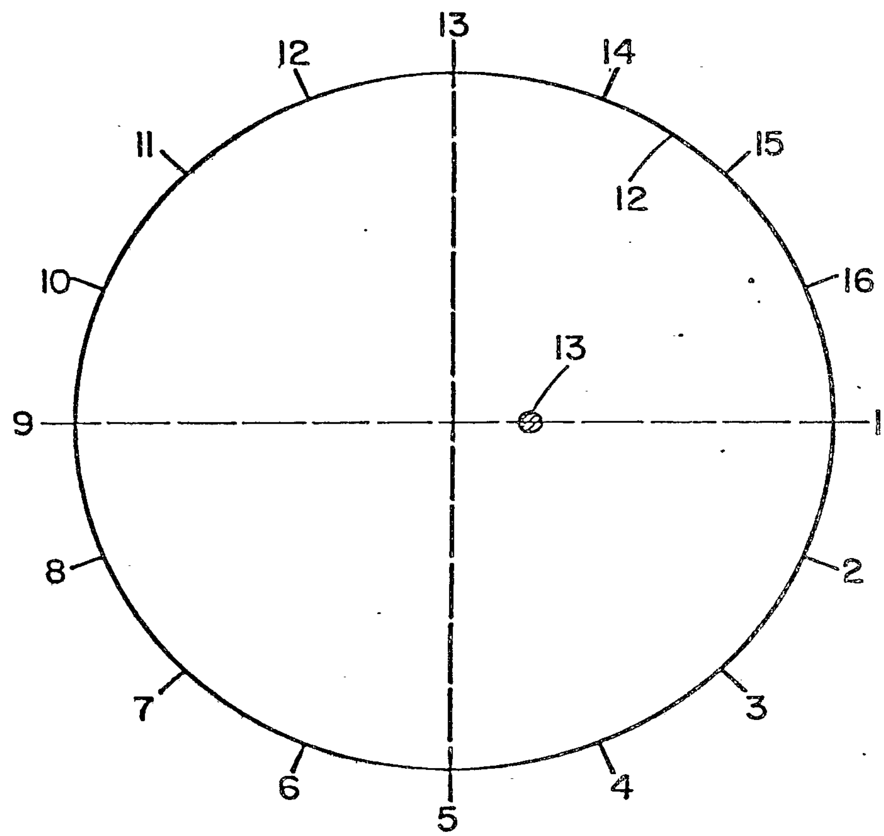

Fig. 3

SPECIFICATION

Low power off centered agitator with partial baffles for buoyant solids mixing drum

The present invention relates to a mixing apparatus comprising a mixing tank having an off-centered agitator and also preferably employing at least two partial baffles which tank is particularly useful for but not limited to the mixing of buoyant particle slurries.

Generally the efficient mixing of buoyant particle slurries is very important to many process operations, as for example in the manufacture of elastomers. In this process buoyant polymer particles in the form of a water slurry are fed to a slurry drum in the finishing sections and then to product extruders. The primary function of the slurry drum is to form a uniform slurry and supply it as feed to the extruders. The slurry drum also provides reliable surge capacity between the polymerization and solids finishing sections. The mixing of these buoyant particles is also an important operation during other aspects of chemical manufacture, such as during the dissolving of polymer particles in processing lubricating oil additives.

The systems used at present for mixing such buoyant particles slurries generally comprise a baffled tank for receiving the slurries containing means for agitating the slurry such as a single or multiple-bladed turbine agitator or stirrer. Ideally, such systems should produce homogeneous, concentrated particle slurries, the prevention of agglomeration of solids in regions of the tank which could lead to plugging of the tank outlets, and a relatively constant change in the outlet slurry concentration to the extruders with changes in the slurry level in the tank. With the present emphasis on energy conservation it is also desired that these systems operate on low power.

Previous attempts to provide efficient mixing systems have included employing unbaffled slurry tanks having a centrally disposed agitator to provide a central vortex in the tank. However, it has been found that various deficiencies exist in such tanks including the need for higher mixing speeds and hence more power than normally anticipated and the concentration of particles between the bottom of the vortex and top of the vortex-creating agitator.

Present mixing designs which include baffling typically have employed full baffles, i.e. baffles which extend vertically for the full length of the tank walls at spaced locations and radially a distance of 1/10 or more of the tank's diameter. This type of full baffling eliminates tank swirl and vortex formation except when the liquid surface is very close to the top of the agitator. The art has also disclosed further mixing arrangements wherein baffles are located at or near the bottom of the tank, at the center of the tank and annular baffles about the agitator at the liquid surface.

The combination of partial baffles and a centered agitator in a mixing system has also been described. In U.S. Patent No. 4,150,900 for example, an improved mixing system is described which employs partial baffling and a central agitator assembly in a mixing tank. The partial baffles described therein comprise small rectangular or triangular finger baffles which are located at various positions in the mixing tank. These baffles are secured about the tank inner surface and are preferably located just below the liquid surface level. In the case of variable level mixing tanks, fixed partial baffles are employed in the form of narrow, elongated rectangles located adjacent to the tank wall and extending from the maximum operating liquid level to the bottom of the tank. If triangular baffles are employed the size of each can be determined by providing a horizontal leg which equals 10% to 15% of tank diameter and a vertical leg which equals 15% to 20% of tank diameter. If rectangular baffles are used the size of each baffle is selected so that the sum of the surface areas of the baffles is the same as the total surface area for four baffles in a triangular configuration. If four rectangular partial baffles are used the width of the rectangles in the radial direction should be approximately 2% or 1/50 of the tank diameter.

In the article, "The Suspension of Floating Solids In Stirred Vessels", G.E.H. Joosten *et. al.*, Trans. I. Chem. E. 55, (July, 220, 1977) a number of experiments using baffled and unbaffled vessels equipped with a centrally disposed agitator were conducted to determine their effect in forming suspensions of floating particles in a liquid. The optimal flow pattern for suspension of the floating particles was found to be a fast rotating liquid whose rotation was disturbed by a single baffle having a width equal to 0.2 of the diameter of the vessel immersed at the top of the liquid to a wetted depth equal to 0.3 of the diameter of the vessel.

The present invention provides a mixing apparatus comprising a cylindrical tank having a bladed down-pumping turbine agitator assembly associated therewith wherein the shaft of the agitator assembly is displaced radially from the central axis of the tank a distance equal to from about 1/10 to 1/4 of the tank diameter. By using such an off-centered agitator it has been found that efficient mixing of buoyant particle slurries is achieved with power savings of up to about 38% compared to centrally or axially disposed agitators.

The apparatus is aslo equipped with at least two partial baffles and preferably with four partial baffles, equally-spaced about the inside circumference of the tank. Such partial baffles comprise vertical, rectangular or triangular members attached to the inside wall of the tank which extend

substantially from the bottom of the tank to the maximum slurry height of the tank, each baffle having a radial width ranging from about 1/36 to 1/100 of the diameter of the tank. Particularly preferred are four equally-spaced rectangular partial baffles having a radial width of about 1/50 of the tank diameter. Such a system of partial baffles in conjunction with an off-centered downpumping agitator provide concentrated, homogeneous particle slurries whose characteristics are not appreciably changed with changes in the slurry level in the tank. Also, such an apparatus provides excellent dispersion and contacting of systems such as, for example, immiscible liquids, gas and liquids, and gas and slurries.

In the drawings: *Figures 1 and 2* show a side view and a top view of the preferred mixing apparatus of the invention having an off-centered agitator and four equally-spaced partial baffles.

Figure 3 is a top view of an unbaffled mixing apparatus having an off-centered agitator showing, by reference numerals, a set of baffle positions about the circumference of the tank.

Referring to Figs. 1 and 2 there is shown a preferred mixing apparatus 11 according to the invention comprising a cylindrical tank 12. An agitator shaft 13 extends axially into the tank and is displaced away from the axis of the tank, as shown by the dotted lines, a distance d varying from about 1/10 to 1/4 of the diameter of the tank. The top portion of the agitator 13 is connected with a means for rotating the shaft (not shown) such as an electric motor. Centrally mounted on the shaft is an agitator assembly 14 shown generally by consisting of 4 equally-spaced downpumping turbine blades pitched to an angle of 45° as shown and positioned adjacent the bottom 19 of the tank. The bottom section 13a of the agitator shaft may be totally supported in the bottom 19 of the tank by a steady bearing. Liquid 16 in the tank may be kept at a constant level or may be varied. Spaced 90° from one another around the inside wall of the tank are preferably four (4) rectangular partial baffles 17, each of which comprises a thin, elongated rectangular member comprised of metal, for example extending from the maximum height of the tank to a point just adjacent the bottom of the tank. Each baffle 17 is secured to the inside wall of the tank by means of a pair of brackets 18 or other conventional securing means fastened at the top and bottom of each baffle. The radial width of each baffle 17 is between about 1/36 and 1/100 of the width of the tank and preferably about 1/50 of the width of the tank. The baffles are spaced from the wall about 1/50 of the width of the tank. The diameter of the agitator assembly 14 should be from about 1/3 to about 1/2 the diameter of the tank.

Fig. 3 shows a top view of a slurry tank 12 having off-centered agitator 13 and also indicates 16 possible positions, spaced 22.5° apart, for locating one or more baffles according to the invention. These positions will be discussed in more detail in connection with the examples.

Experimentally, it has been found that the use of an off-centered agitator in a tank design such as described above for forming buoyant particle slurries provides consistently higher outlet slurry concentrations than tanks equipped with a centered agitator. Use of this invention, however, is not restricted to mixing of buoyant particle slurry and has broad utility as mentioned above for immiscible liquids, gas and liquid, and gas and slurries and the like. Moreover, lower tip speeds and hence lower power is required by the off-centered agitator according to the invention than a centered agitator to achieve the same degree of mixing. This savings in power is from about 50% to 80% compared to multiple-turbined central agitators and fully baffled tanks and up to about 38% in the case of single turbined agitators.

By employing at least two equally spaced partial baffles with an off-centered agitator mixing efficiency is further enchanced. By using four equally-spaced partial baffles, optimum mixing efficiency is obtained with changes in outlet slurry concentration being relatively small with increases in slurry level.

It has also been found that the baffle radial width is important to the mixing efficiency of the invention. At widths of from between 1/36 and 1/100 of tank diameter, and preferably 1/50 of tank diameter, concentrated and homogeneous slurries are obtained. At widths substantially above and below these ranges the slurry characteristics become unsatisfactory.

Triangular baffles may be similarly employed in this invention provided they have surface areas equivalent to the rectangular partial baffles described above.

In order to more fully define the present invention, the following examples are given.

Example 1

In this and the following examples, a 0.9 m diameter tank with a flat bottom was employed comprised of Plexiglas and having a height of 1.8 m. A 0.3 m diameter 45° downpumping pitched blade turbine with four (4) 54 mm wide blades was mounted on a vertical agitator shaft displaced from the axis of the tank by 90 mm (1/10 of tank diameter). The agitator drive equipment consisted of a 3 HP electric motor which, through a variable speed drive, was capable of rotating the agitator at speeds of up to 260 RPM. The agitator shaft was supported at the tank bottom by a steady bearing. Four baffles, each 1/50 of the tank diameter, were mounted at equal intervals inside the internal periphery of the tank spaced from the tank wall a

distance equal to 1/50 of the tank diameter. This arrangement is shown in Figs. 1 and 2.

A Vibrac TQ–5120 (range 0–5120 in-oz) torque transducer was included in the shaft for measurement of torque. The TQ–5120 unit was also equipped with a magnetic speed transducer which put out 60 pulses per shaft revolution. This was translated to RPM by means of a frequency meter. A slurry outlet, 127 mm above the tank bottom, was connected to the inlet of a positive displacement pump by a 25 mm diameter pipe. The outlet from the pump was directed back into the tank to provide recycle loop. In all the examples the slurry consisted of 4% by weight of 3.2 mm polypropylene pellets in water. The outlet slurry concentration was measured by collecting samples at the recycle loop into the tank. The pellets from each sample were filtered and weighed while the volume of water was measured to determine outlet concentration.

In this example a comparsion of mixing characteristics was made between the off-centered agitator and a centered agitator used in the same tank having the same blade pitch and width as the off-centered agitator. The speeds used for both agitator types were 200 and 225 RPM. Outlet slurry concentrations were determined for both agitators as the percent of bulk concentration at different slurry levels in the tank measured as the percent (%) of full height of the tank.

The results are given in Table 1 below.

Table 1

Slurry Level (% of Full height)	OUTLET SLURRY CONC. (% of Bulk Concentration) Centered At Speed—RPM 200	225	Off-Centered At Speed—RPM 200	225
48	56.1	65.6	71.3	74.2
98	37.9	50.3	58.0	61.8

As Table 1 shows the off-centered agitator provided consistently higher outlet slurry concentrations at each slurry level than those with the centered agitator. In addition, the change in outlet slurry concentration with change in slurry level was smaller for the off-centered agitator than for the centered agitator.

Next, agitator speeds required to achieve an outlet slurry concentration equal to 60% of the bulk concentration were then determined for both the centered and off-centered agitator. It was found that lower speeds were required by an off-centered agitator than a centered agitator to achieve the same degree of mixing. The difference in these speeds decreased as the slurry level was increased. For the tank design described above the maximum slurry level was 93% which corresponds to a 14% lower agitator speed requirement than the centered agitator system. This can amount to a savings of about 38% in power consumption.

Example 2

In this example, outlet slurry concentration measured as the percent of bulk concentration was determined at an 83% slurry level using the tank and baffling arrangement described in Example 1 except that the agitator assembly comprised a 15" diameter pitched blade turbine, the agitator shaft of which was displaced a distance equal to 0.225 of the tank diameter. The agitator speeds used were 125 and 150 RPM. Table 2 below summarizes the results.

Table 2

AGITATOR SPEED (RPM)	OUTLET SLURRY CONCENTRATION (% of Bulk Concentration)
125	66
150	76

As Table 2 shows, high outlet slurry concentrations were obtained at each speed using an agitator centrally offset a distance nearly 1/4 of the tank diameter.

Example 3

In this Example, a series of four (4) equally spaced partial baffles as shown in Fig. 1 were inserted around the inside wall of the tank at the following positions, shown in Fig. 3:

Series A—Positions 1, 5, 9 and 13
Series B—Positions 2, 6, 10 and 14
Series C—Positions 3, 7, 11 and 15
Series D—Positions 4, 8, 12 and 16

In each series, the baffle width was varied from 1/36 to 1/50 to 1/100 of the tank diameter, *viz* 9 mm, 18 mm and 25 mm respectively. Stirring of the off-centered agitator was carried out at speeds of 200 and 225 RPM. Outlet slurry concentrations measured as the percent of bulk concentration were determined for each baffle width in each series. The slurry level was 100% of full tank height. Table 3 below summarizes the results.

Table 3

Speed RPM	Outlet Concentration as % of Bulk Concentration Using Four (4) Baffles											
	SERIES A Baffle Width-mm			SERIES B Baffle Width-mm			SERIES C Baffle Width-mm			SERIES D Baffle Width-mm		
	9	18	25	9	18	25	9	18	25	9	18	25
225	37.0	54.8	22.3	45.8	65.3	32.5	46.0	58.8	24.0	45.8	61.8	37.0
260	49.5	71.3	45.8	49.8	56.0	52.8	51.8	64.5	41.0	51.8	61.0	46.3

As Table 3 shows, baffle widths from 1/36 to 1/100 of tank diameter in conjunction with an off-centered agitator provide efficient mixing. However, a baffle width of 1/50 of tank diameter is particularly preferred since it provided consistently higher slurry outlet concentrations at the speeds employed. The position of the baffles did not significantly vary the outlet concentrations.

Example 4

In this Example the effect of slurry level on the concentration of outlet slurry was measured using two and four partial baffles with an off-centered agitator as shown in Fig. 1 having radial widths of 1/50 of tank diameter. For each baffle arrangement, the slurry level was raised to 28%, 46% and 100% of full height while outlet slurry concentrations were measured at agitator speeds of 200 and 225 RPM. Table 4 summarizes the results.

Table 4

	Outlet Concentration (% of Bulk Concentration)					
Agitator	2 Baffles			4 Baffles		
Speed	Slurry Level—% of Full Height			Slurry Level—% of Full Height		
RPM	28	46	100	28	46	100
200	19.5	41.8	72.3	74.5	71.3	58.0
225		35.5	89.0		74.3	61.8

With two baffles the outlet slurry concentration increases from about 20% to 90% of bulk concentration as the slurry level is increased from about 30% to 100%. With four baffles the outlet slurry concentration decreases from about 75% to 60% over the same slurry level range. This indicates that a four baffle arrangement is preferable to a two baffle arrangement for buoyant particle slurries because of the relatively small change in outlet slurry concentration with varying slurry levels.

CLAIMS

1. A mixing apparatus comprising:

(a) a cylindrical tank;

(b) an agitator shaft rotatably mounted in said tank, said shaft being radially displaced from the axis of said tank a distance of from about 1/10 to 1/4 of the tank diameter;

(c) a bladed turbine assembly centrally mounted on said shaft; and

(d) at least two baffles mounted on the inside wall of said tank.

2. A mixing apparatus according to claim 1 wherein said baffles have a radial width of between about 1/36 and 1/100 of said tank diameter.

3. A mixing apparatus according to claim 2 wherein said baffles comprise rectangular members having a radial width of about 1/50 of said tank diameter.

4. A mixing apparatus according to claims 1–3 wherein each baffle is spaced from the inside wall of said tank a distance equal to 1/50 of the tank diameter.

5. A mixing apparatus according to claims 1–4 which comprises four equally spaced baffles.

6. A mixing apparatus according to claims 1–5 wherein the tank is adapted to receive a liquid or slurry up to a predetermined level in said tank; and wherein said baffles extend substantially from said tank bottom to said predetermined level.

7. A mixing apparatus according to claims 1–6 wherein four equally-spaced rectangular baffles are provided.

8. A mixing apparatus according to claims 1–7 wherein said bladed turbine assembly comprises four equally-spaced downpumping turbine blades, each of said blades pitched at an angle of 45°.

9. A mixing apparatus according to claims 1, 2 and 4–7 wherein each of said baffles is a triangular baffle.

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ABSTRACT:

CHG DATE=19990617 STATUS=O> A mixing apparatus comprises a cylindrical tank 12 having a down- pumping turbine bladed agitator 14 the shaft 13 of which is displaced radially from the axis of the tank by a distance of from about 1/10 to 1/4 of the tank diameter and at least two baffles 17, preferably equally-spaced, mounted on the inside wall of the tank, each of the baffles comprises a rectangular member extending substantially from the bottom of the tank to the maximum slurry level of the tank and having a radial width of between about 1/36 and 1/100 of the tank diameter. Four equally-

spaced baffles are particularly preferred, each having a radial width of about 1 /50 of the tank diameter.